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AUTHOR(S):

SHINBORI, Atsuki; KOYAMA, Nobuyuki; HAYASHI, Hiroo; NOSE, Masahito; HORI, Tomoaki; OTSUKA, Yuichi; TSUDA, Toshitaka; IUGONET Project Team

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Long-term variation in the upper atmosphere as seen in the amplitude of the geomagnetic solar quiet daily variation

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#Atsuki Shinbori [1]; Nobuyuki Koyama [2]; Hiroo Hayashi [1]; Masahito Nose [2]; Tomoaki Hori [3]; Yuichi Otsuka [3]; Toshitaka Tsuda [1]; Hayashi Hiroo IUGONET Project Team.

1. Research Institute for Sustainable Humanosphere (RISH), Kyoto University, Japan. 2. World Data Center for Geomagnetism, Kyoto University, Japan. 3. STEL, Nagoya University, Nagoya, Japan.

E-mail: shinbori@rish.kyoto-u.ac.jp

1. Introduction

1.1 Geomagnetic solar daily quiet variation

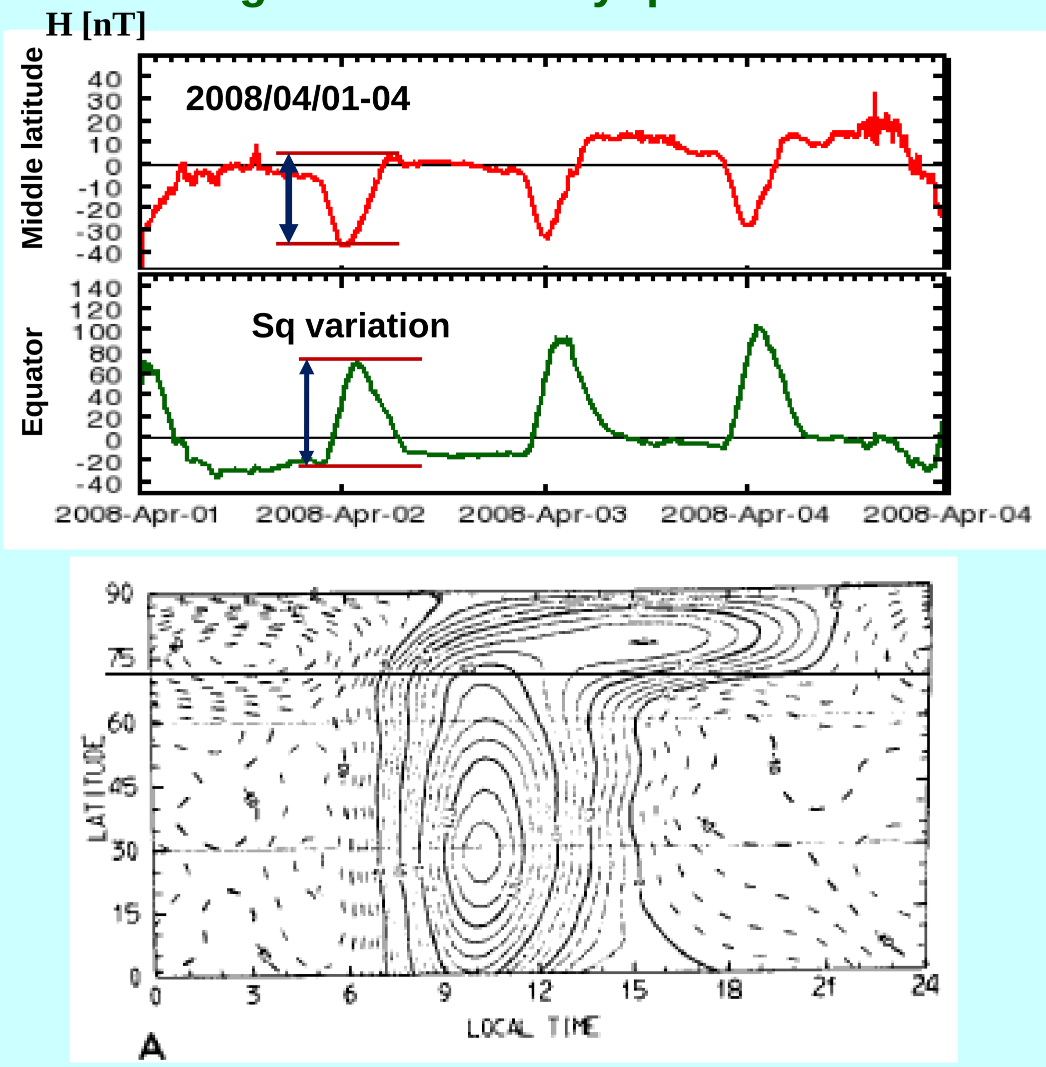


Fig.1: An example of Sq variation observed at middle latitude and equator and equivalent current plotted as functions of local time and latitude derived from the KRM method [Matsushita, 1975].

The daily variation of geomagnetic field during solar quiet days has been called Sq (geomagnetic Solar daily Quiet variation), and is mainly produced by ionospheric currents. The currents are driven by ionospheric dynamo of the E-region altitude via interaction between neutral and ionized particles. Since the amplitude of the Sq field strongly depends on ionospheric conductivity and neutral wind in the lower thermosphere and mesosphere, investigation of the Sq field using the long-term observation data is essential for understanding the long-term variation in the upper atmosphere.

Recently, Elias et al. [2010] reported that the Sq fields observed at Apia, Fredericksburg and Hermanous show significant increasing trends for the period 1960-2001. They interpreted the Sq trends as effects on both secular variation in the ambient magnetic field intensity and upper atmospheric changes associated with global warming.

1.2 Problems of the past studies and purpose of this study

However, since Elias et al. [2010] analyzed geomagnetic field data obtained only at three stations for a short period, a global feature of the long-term Sq trends has remained unknown. They did not also perform a comparison between the Sq field and neutral wind in the lower thermosphere and mesosphere.

Then, the purpose of the present study is to clarify characteristics of the long-term variation in the Sq field (latitudinal and longitudinal dependence) using the long-term observation data of geomagnetic field provided from World Data Center for Geomagnetism, Kyoto University. For data search and analysis of the present study, we took advantage of metadata data search system and data analysis software (UDAS) developed in the IUGONET project.

2. Date sets and analysis

2.1 Observation data used in the present analysis

1. Geomagnetic field (1 hour data since 1900) :WDC, Kyoto Univ.
2. Geomagnetic index (Kp, 1932-2010): WDC, Kyoto Univ.
3. F10.7 flux (1947-2010) :NGDC/NOAA

2.2 Identification of quiet day and Sq amplitude

1. Definition of quiet day

   The maximum of Kp index is less than 4 every day.

2. Sq amplitude

   Difference between the maximum and minimum values of the daily variation of the H-component of geomagnetic field during quiet.

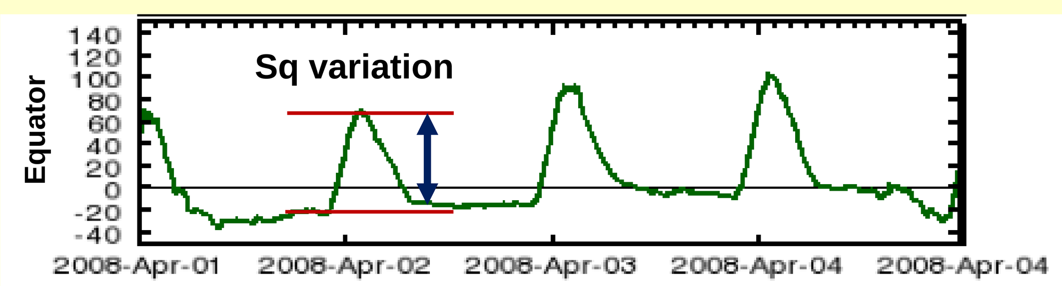


Fig.2: An example of Sq field observed at the equator during April 1-4, 2008.

2.3 Residual amplitude of Sq fields to filter out the solar activity

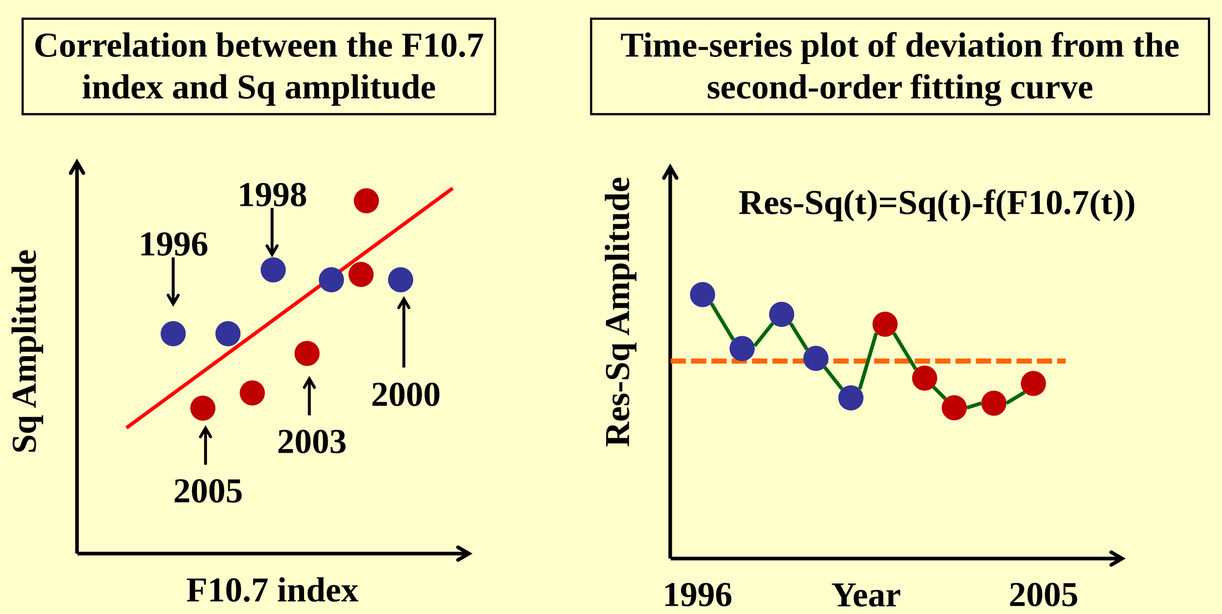


Fig. 3: A schematically picture of analysis method to obtain the residual amplitude of the Sq fields from correlation with the F10.7 index.

We defined the residual Sq amplitude as the deviation from the second-order fitting curve between the F10.7 index and Sq amplitude shown in Figure 3.

3. Results

3.1 Long-term variation in the Sq amplitude

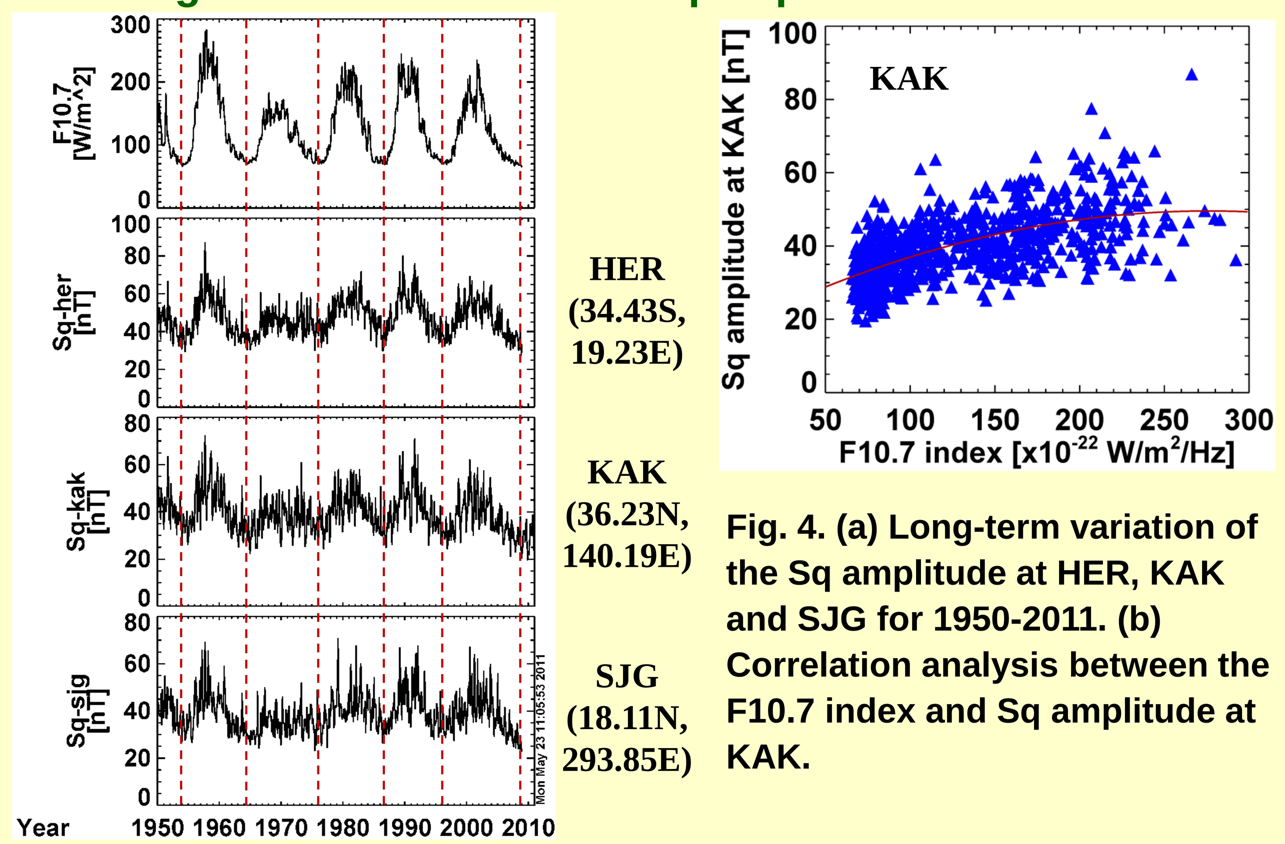
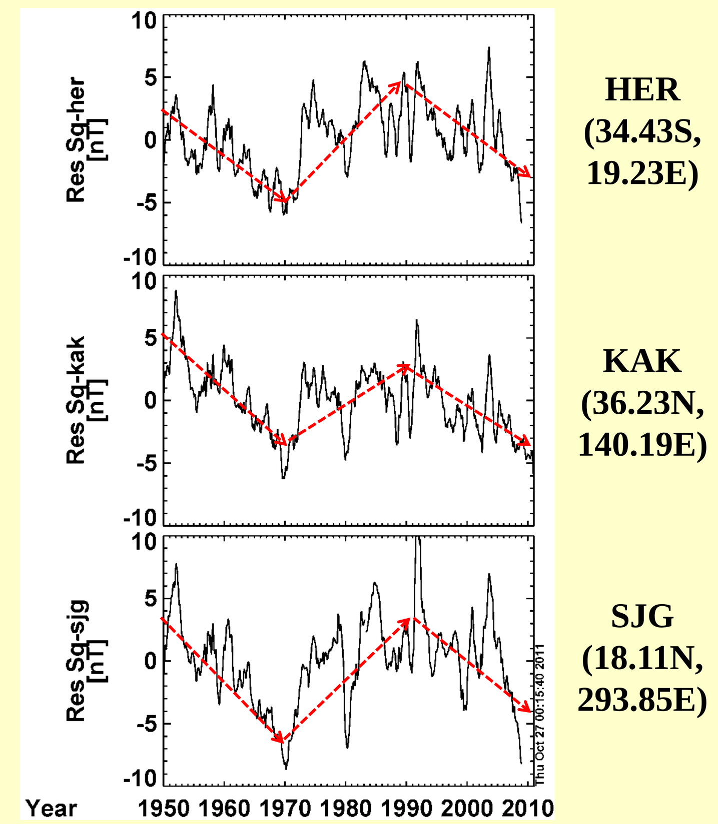


Fig. 4. (a) Long-term variation of the Sq amplitude at HER, KAK and SJG for 1950-2011. (b) Correlation analysis between the F10.7 index and Sq amplitude at KAK.

The Sq amplitude at all the stations varies with 11-yr solar activity dependence, and is proportional to the F10.7 index according to the second-order curve (not liner one).

3.2 Long-term trends of residual Sq amplitude



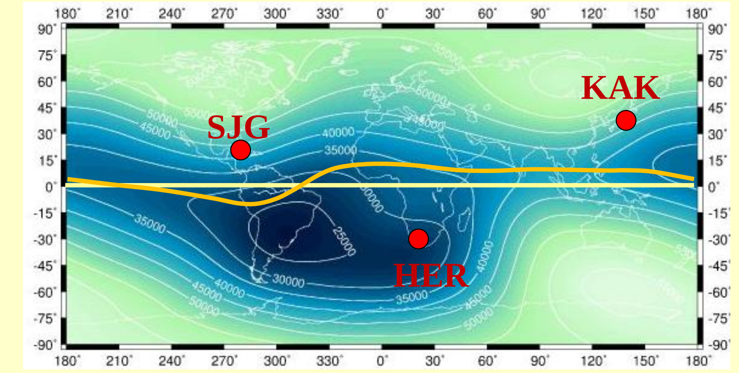


Fig. 5. (a) Long-term trends of the residual Sq amplitude at HER, KAK and SJG for 1950-2011. These data are 1-month running averages. The average inclination of the Sq trend is indicated by the red arrow. (b) Location of the three stations. The orange line indicate the dip equator.

The long-term variations of the residual Sq amplitude show significant decreasing, increasing and decreasing trends for 1950-1969, 1970-1989 and 1990-2009, respectively.

3.3 Global features of the trends of residual Sq amplitude

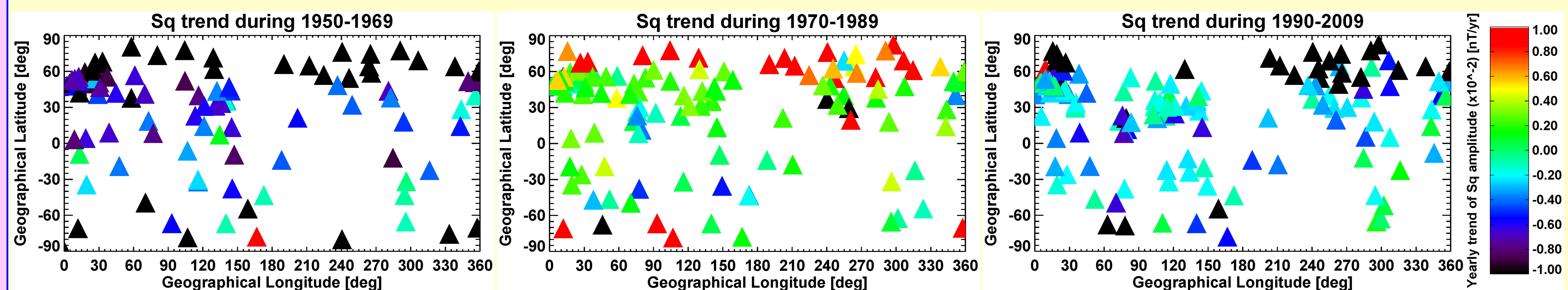


Fig. 6: Global distribution of the long-term trends of residual Sq amplitude as function of geographical latitude and longitude for 1950-1969, 1970-1989, and 1990-2009. The inclination of the Sq trends is indicated by color scale between -1.0 and 1.0.

The long-term variations of the residual Sq amplitude in the entire region from the north and south poles show significant decreasing, increasing and decreasing trends for 1950-1969, 1970-1989, and 1990-2009, respectively. The inclination of the Sq trends tends to increase with increasing latitude. This result indicates that the long-term Sq trends do not always tend to increase. However, only for the period of 1960-1989, the Sq trends are consistent with that reported by Elias et al. [2010]. In the future study, we try to perform a quantitative estimation of contribution of secular variation of the ambient magnetic field intensity to the long-term Sq trends, from comparison with ionospheric conductivity calculated using the IRI-07 and MSIS-00 models.

4. Conclusion

In order to clarify a global feature of the long-term Sq trends, we performed the integrated analysis of the observation data of geomagnetic field with 1h time resolution , solar F10.7 index during 1950- 2011. We showed several new and important results as follows.

1. The amplitude of the Sq field observed in a wide region from the north to the south poles depends strongly on 11-yr solar activity. The Sq amplitude is also proportional to the solar F10.7 index according to the second-order curve (not linear one).
2. The long-term variations of the residual Sq field showed significant decreasing, increasing and decreasing trends for 1950-1069, 1970-1989 and 1990-2009, respectively. Only the positive trend during 1970-1990 is consistent with that of Elisa et al. [2010]], who proposed that the long-term increase of Sq field contributes to both the decrease of the ambient magnetic field intensity and cooling effect of the upper atmosphere due to greenhouse effect. Therefore, their interpretation of the long-term Sq trends can not always be adapted for all the periods.
3. The 20-yr intervals of decreasing and increasing trends of the residual Sq field may suggest a characteristic period of changes in the Earth's upper atmosphere without dependence on solar activity. In the future study, we try to derive a contribution of secular variation of the ambient magnetic field intensity to the long-term Sq trends, from comparison with ionospheric conductivity calculated using the IRI-07 and MSIS-00 models.